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Tiva Based Daughter Board For Firebird V.

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Abstract

The objective of the project is to design two daughter boards for firebird V which has the following features:

- Compatible With TIVA based platform.
- Must support all the necessary features of firebird.

The deliverables expected were

- 2 working Daughter boards
  - **Plug and Play Board** with TIVA launchpad
  - **uC based Board** with TM4C123GH6PM Microcontroller.
- Hardware and software manual for anyone using it in future.
- All the demo codes for assistance.

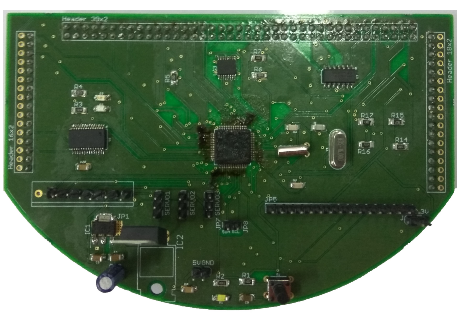


Figure1: uC based board

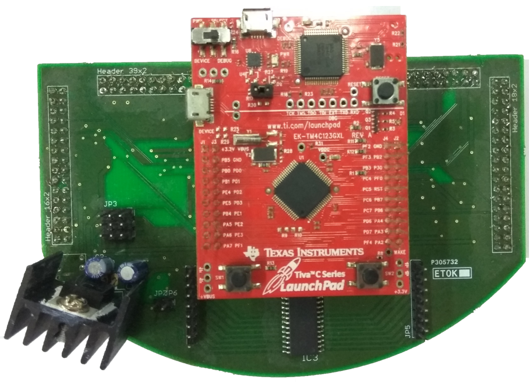


Figure2: Plug and Play board

Completion status

The project was divided in many small tasks which were to be completed in given time. Though we refrain from mentioning that long list but still will give some important one.

- Learning Tiva Platform.
- Finding solution for limitations offered by Tiva, like limited GPIO pins and limited ADC channels.
- Utilizing the functionality provided to the maximum.
- Creating schematic and layout for the daughter boards.
- Testing the boards and writing all the test codes.
- Making hardware and software manuals.

1.1 Hardware parts

- List of hardware used :
  - Tiva launchpad.
  - TM4C123GH6PM Microcontroller.
  - MCP23017 port expander.
  - ADC128D818 external ADC.
  - Voltage regulator(lm1117,7805).
  - FT232
- Detail of each hardware:
  1. Tiva Launchpad: It is a micro-controller board by Texas Instruments that has on board programmer with real time debugging feature. The micro-controller is very efficient with system clock up to 80MHz and CAN protocol. It has 40 GPIO pins with interrupt on each pin. In addition, it has Two general-purpose user switches, a reset switch, power LED, and user-programmable RGB LED. The tutorial and more information can be read from Datasheet.

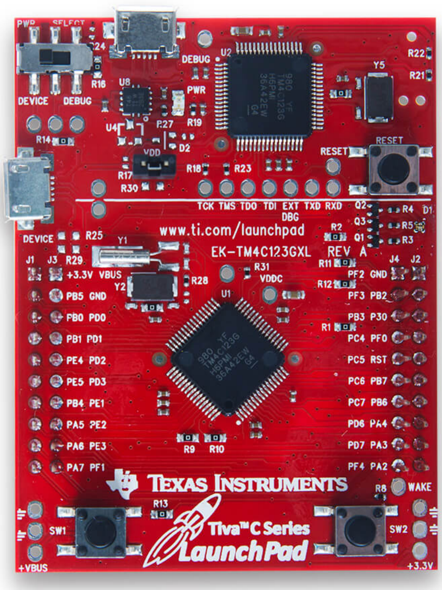


Figure3: TIVA Launchpad
Picture courtesy: Texas Instruments Manual

2. TM4C123GH6PM is a ARM cortex M4 based micro-controller that is used as a controller of the Tiva Launchpad. It has the following features
   - Upto 80MHz Clock
   - 256KB Flash
   - 32KB RAM
   - 2-KB EEPROM
   - On-chip ROM with drivers and boot loaders
   - 12 channel 12-bit ADCs
   - 16 Motion PWM channels
   - 24 Timer/Counters
   - 4 SPI/SSI, 2 CAN, 4 I2C, 8 UART
   - USB Host/Device/OTG
   - Low-power hibernation mode
   - 43 GPIO pins

   You can read Datasheet for more details.

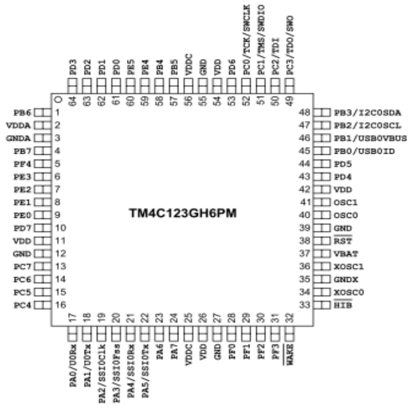


Figure4: TM4C123GH6
Picture courtesy: Texas Instruments Manual

3. Voltage Regulators:The voltage source available on the Firebird is 9.6V. But the TIVA platform works on 3.3V and the servos can operate up to 6V. So there must be 3 different voltage levels on the board.
   The uC based board has 2 voltage regulators. LM117 is used to convert 9.6V to 3.3V and power the microcontroller. 7805 is used for powering the servo motors.
   The Plug and Play board has an inbuilt voltage regulator, so it is directly connected to 5V, 300mA source. 7805 is used to convert 9.6V to 5V and power the servo motors.
   Datasheets for3.3 volts regulator LM1117, and 5 volts regulator 7805 5 volts regulator can be accessed from the links.

Figure5: TM4C123GH6
Picture courtesy: element14

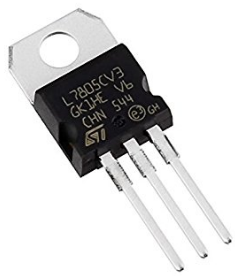
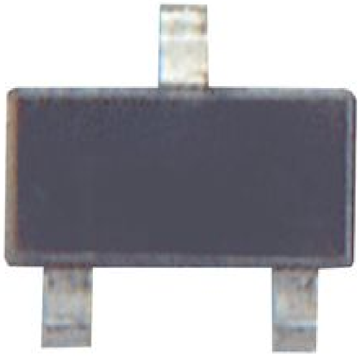


Figure6: TM4C123GH6
Picture courtesy: element14

4. Level Converters TIVA platform operates at 3.3V and the Firebird operates at 5V. Directly connecting these pins to the TIVA may be fatal. So for proper level maintenance, a level converter is used. A

bidirectional MOS-FET based level converter is used in this case. The level converter is necessary for input pins and may or may not be used in output pins. In the Daughter boards, Level converter is used for interfacing the position encoders of the motors. Datasheet of MOSFET is also provided.



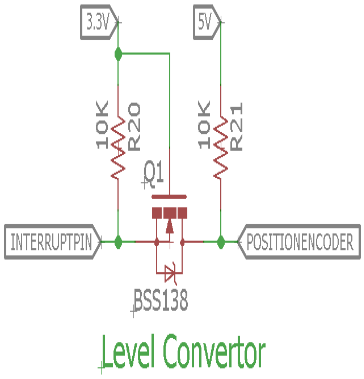


Figure7: BSS138
Picture Courtesy: element14

Figure8: Schematic

5. Port Expander(MCP23017):TM4C123GH6PM has 64 pins out which 43 are GPIO pins. This limits our application to read input and respond correspondingly. To increase the number of GPIO and there interrupts we have used I2C compatible a port expander MCP23017. It has 2 PORTS A and B, with each port having 8 Pins.The interrupts on each pin can also be monitored. To read more about it, download the datasheet from here.The schematic of the connection is shown below.Keep in mind that I2C SCL and SDA have already been pulled up using 10K resistor.Datasheet of the port expander can be fount here.

Figure9: MCP23017
Picture Courtesy: Microchip

6. FT232 is used for Serial Communication between TM4C123GH6PM and computer. FT232 is used for USB to Serial UART interface. It has an internal oscillator and EEPROM.
   This IC is excluded in Plug and Play board as it already has provision for serial communication on board.

Figure10: MCP23017
Picture Courtesy: FTDI

1.2 Software used

- **Autodesk Eagle** can be downloaded from this link
- **Installing Autodesk Eagle:**

1. Download the installer from the link provided above and run *Autodesk_EAGLE_8.0_English_Win_64bit.exe*.
2. Select the Yes button on the next Windows security dialog box.
3. Accept the lisence agreement and click on the next button

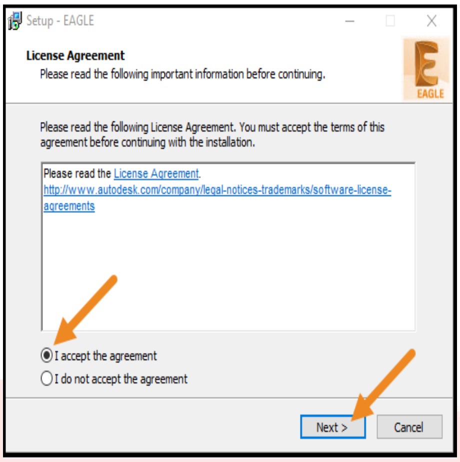


Figure11

4. On the final step, click on the *Install* button

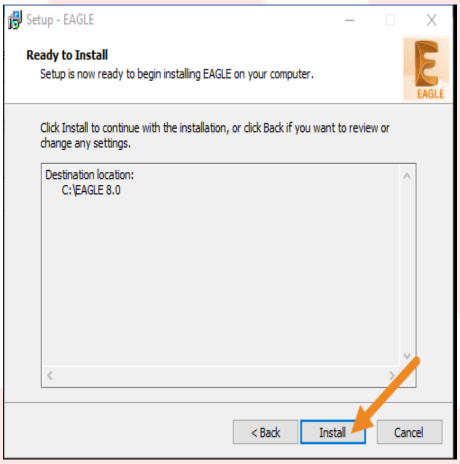


Figure12

5. With your installation complete go ahead and open Autodesk EAGLE. The first time you run Autodesk EAGLE, youll need to sign in to your existing Autodesk account or create a new account.

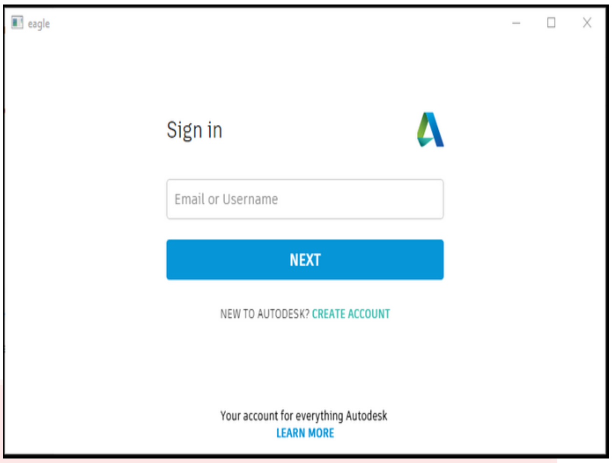


Figure13

Note: Autodesk gives free 3 years premium subscription to student lisences.

- **Code Composer Studio** version 7.1.0 can be downloaded from this link,
- **Installing CCS Studio:**

  After the installer has started follow the steps mentioned below:

1. Accept the Software License Agreement and click Next.

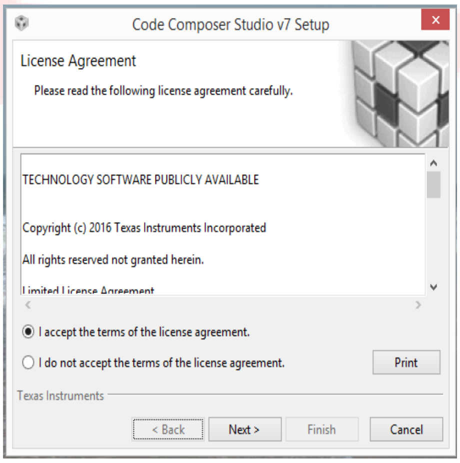


Figure14.

2. Select the destination folder and click next.

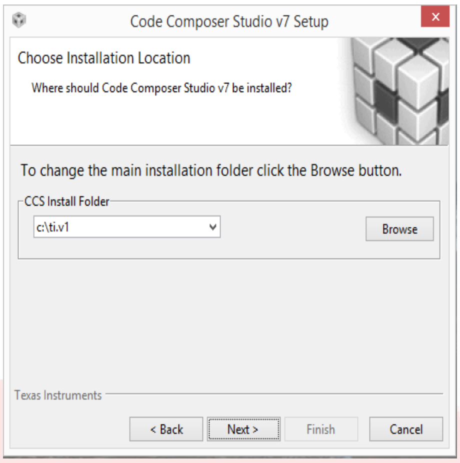


Figure15.

3. Select the processors that your CCS installation will support. You must select "TM4C12X Arm Cortex M4". You can select other architectures, but the installation time and size will increase.

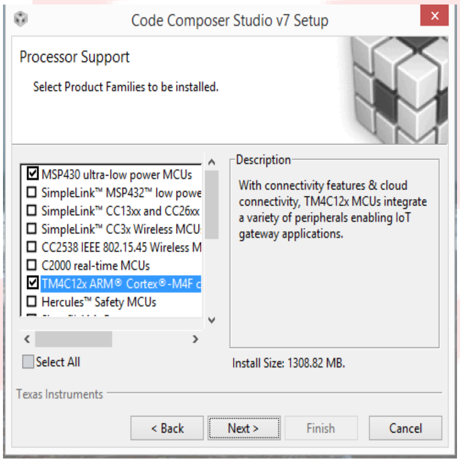


Figure16 .

4. Select debug probes and click finish

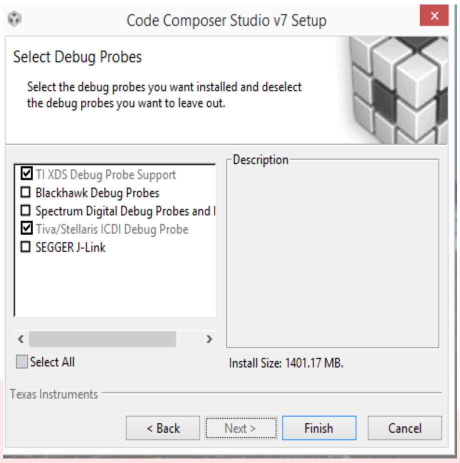


Figure17.

5. The installer process should take 15 - 30 minutes, depending on the speed of your connection. The offline installation should take 10 to 15 minutes. When the installation is complete, uncheck the Launch Code Composer Studio v7 checkbox and then click Finish.There are several additional tools that require installation during the CCS install process. Click Yes or OK to proceed when these appear.

6. Install TivaWare for C Series (Complete). Download and install the latest full version of TivaWare from: TivaWare. The filename is SW-TM4C-x.x.exe . This workshop was built using version 1.1. Your version may be a later one. If at all possible, please install TivaWare into the default location.

You can find additional information at these websites:
Main page: www.ti.com/launchpad
Tiva C Series TM4C123G LaunchPad:
http://www.ti.com/tool/ek-tm4c123gxl
TM4C123GH6PM folder:
http://www.ti.com/product/tm4c123gh6pm
BoosterPack webpage: www.ti.com/boosterpack
LaunchPad Wiki:
www.ti.com/launchpadwiki

For understanding the launchpad properly and to learn more about Tiva it is strongly recommended to go through the webpage TIva Worshops and download and read the workbook

1.3 Assembly of hardware

Circuit Diagram

- **Plug and Play board**

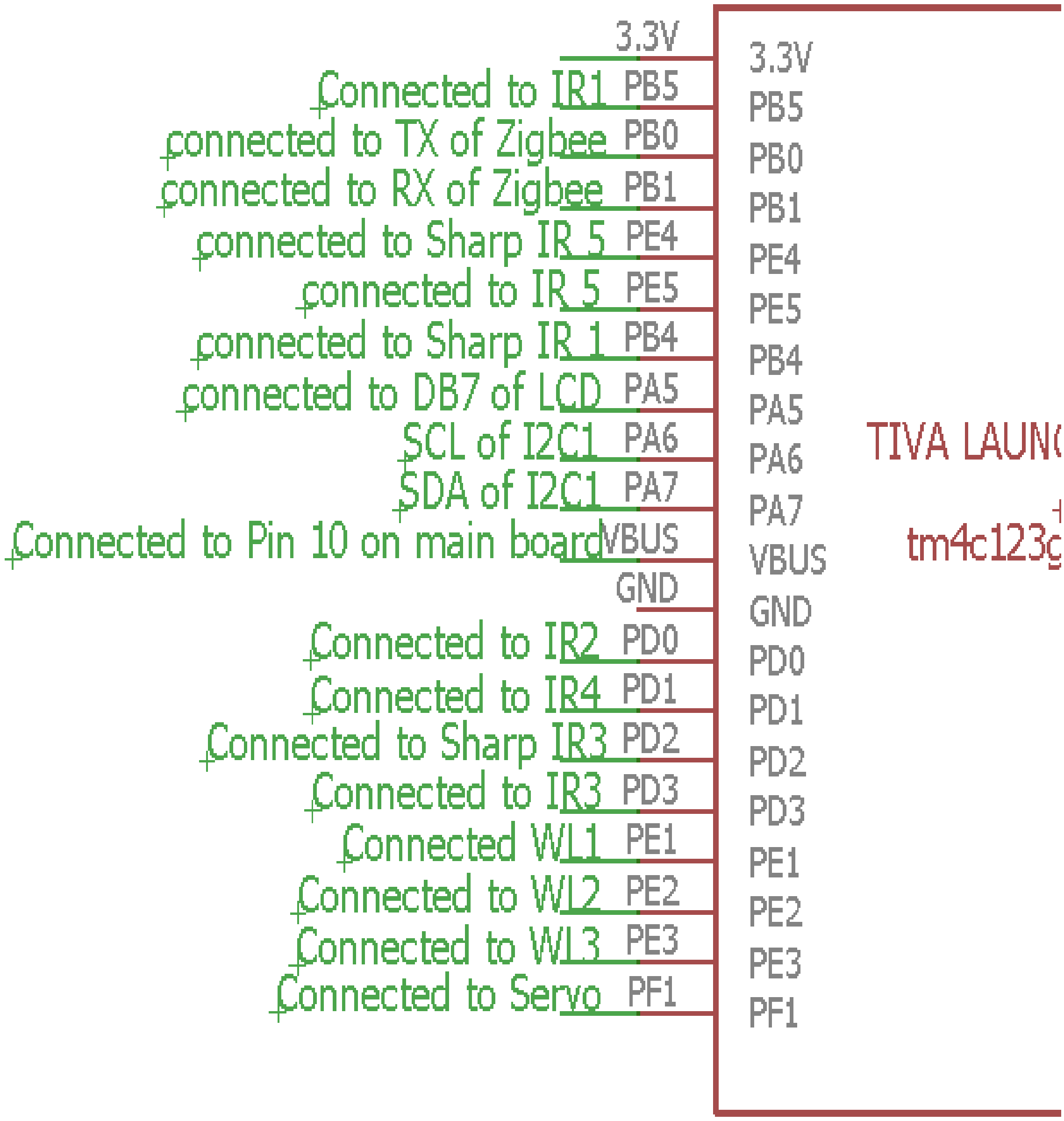


Figure18

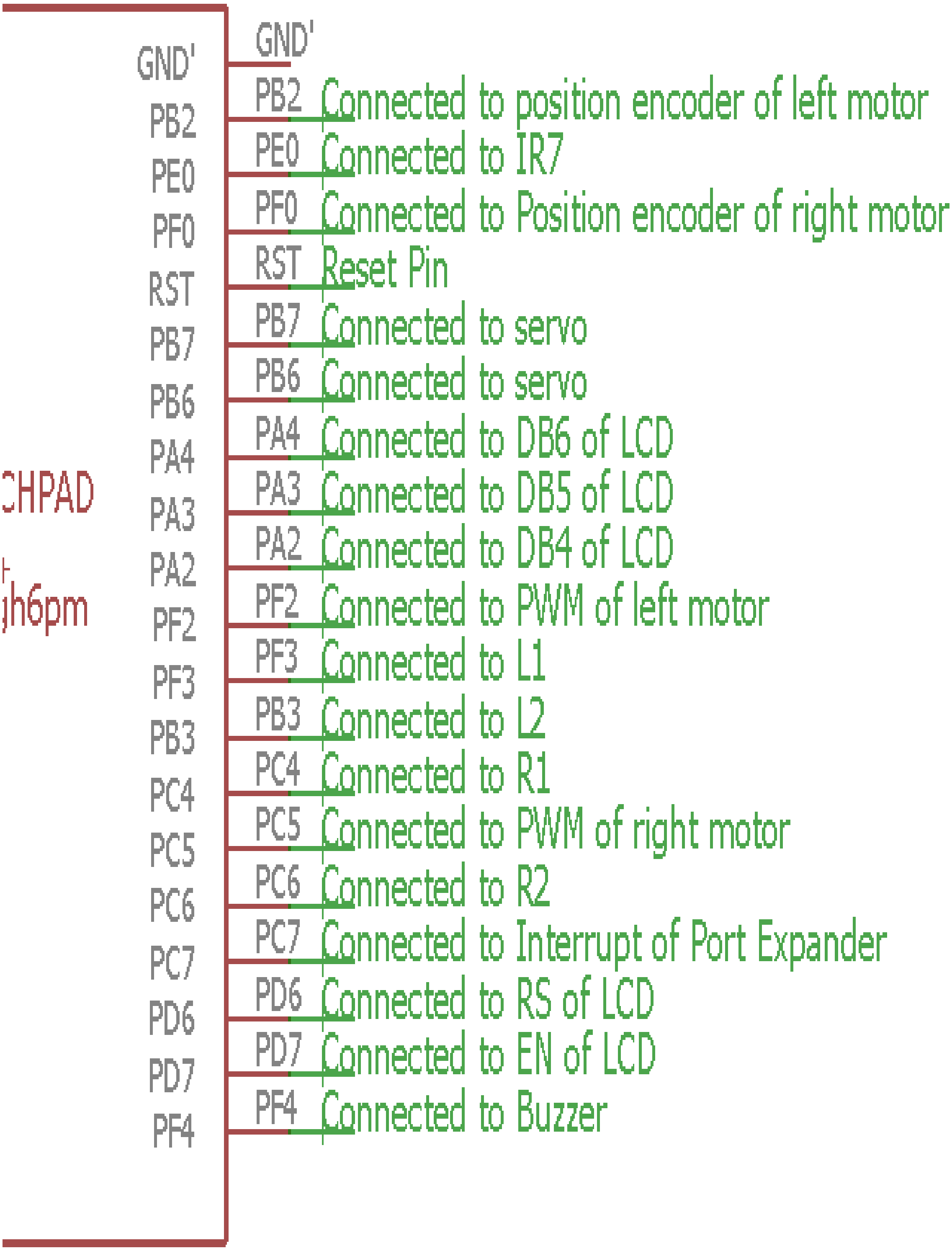

GND'
PB2
PE0
PF0
RST
PB7
PB6
PA4
CHPAD
PA3
PA2
jh6pm
PF2
PF3
PB3
PC4
PC5
PC6
PC7
PD6
PD7
PF4
GND'
PB2 Connected to position encoder of left motor
PE0 Connected to IR7
PF0 Connected to Position encoder of right motor
RST Reset Pin
PB7 Connected to servo
PB6 Connected to servo
PA4 Connected to DB6 of LCD
PA3 Connected to DB5 of LCD
PA2 Connected to DB4 of LCD
PF2 Connected to PWM of left motor
PF3 Connected to L1
PB3 Connected to L2
PC4 Connected to R1
PC5 Connected to PWM of right motor
PC6 Connected to R2
PC7 Connected to Interrupt of Port Expander
PD6 Connected to RS of LCD
PD7 Connected to EN of LCD
PF4 Connected to Buzzer

Figure19

- **uC based board**

Figure20


33-HIB
34-XOSC0
35-GNDX
36-XOSC1
37-VBAT
38-RST
39-GND
40-OSC0
41-OSC1
42-VDD
43-PD4/U6RX/USB0DM/WT4CCP0
44-PD5/U6TX/USB0DP/WT4CCP1
45-PB0/T2CCP0/U1RX/USB0ID
46-PB1/T2CCP1/U1TX/USB0VBUS
47-PB2/I2C0SCL/T3CCP0
48-PB3/I2C0SDA/T3CCP1
49-PC3/SWO/T5CCP1/TDO
50-PC2/T5CCP0/TDI
51-PC1/SWDIO/T4CCP1/TMS
52-PC0/SWCLK/T4CCP0/TCK
53-PD6/M0FAULT0/PHA0/U2RX/WT5CCP0
54-VDD
55-GND
56-VDDC
57-PB5/AIN11/CAN0TX/M0PWM3/SSI2FSS/T1CCP1
58-PB4/AIN10/CAN0RX/M0PWM2/SSI2CLK/T1CCP0
59-PE4/AIN9/CAN0RX/I2C2SCL/M0PWM2/U5RX
60-PE5/AIN8/CAN0TX/I2C2SDA/M0PWM5/M1PWM3/U5TX
63-PD2/AIN5/M0FAULT0/SSI1RX/SSI3RX/USB0EPEN/WT3CCP0
64-PD3/AIN4/IDX0/SSI1TX/SSI3TX/USB0PFLT/WT3CCP1
32.7 kHz Crystal
32.7 kHz Crystal
3.3V
Connected to Reset Switch
16 MHz Crystal
16 MHz Crystal
Connected to DB4 of LCD
Connected to DB5 of LCD
Connected to L1
Connected to L2
I2C
I2C
Connected to JTAG TDO
Connected to JTAG TDI
Connected to JTAG TMS
Connected to JTAG TCK
Connected to DB6 of LCD
Connected to IR5
Connected to Sharp IR5
Connected to IR4
Connected to IR3
Connected to WL3
Connected to WL2
Connected to WL1
Connected to Sharp IR3
C8
C14
C13
C12
C11
VDD
0.01uF
0.01uF
0.01uF
0.01uF
0.01uF
2.2uF
GND
C2
C1
C10
VDDC
0.01uF
0.01uF
1.0uF
2.2uF
GND

Figure21

Step 1

Remove the screws marked in figure using a screw driver. Remove the top cover and carefully unplug the Daughter board.(Use the help of a wedging device if necessary)

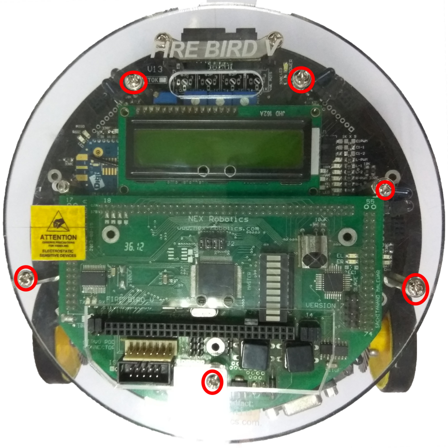


Figure22

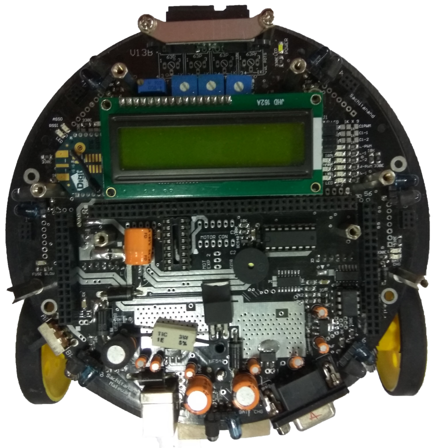


Figure23

Step 2

Plug the TIVA based Daughter carefully into slot shown below. Ensure proper allignment of the male burge connector while plugging in the daughter board. The final assembled board looks as shown in figure.

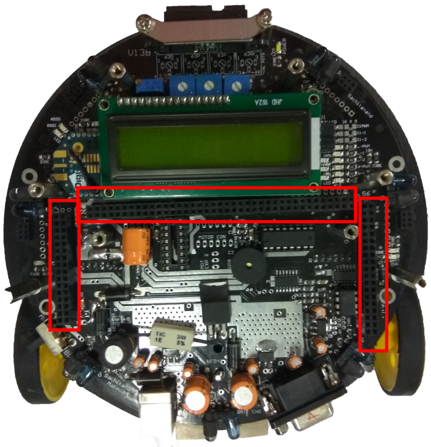


Figure24

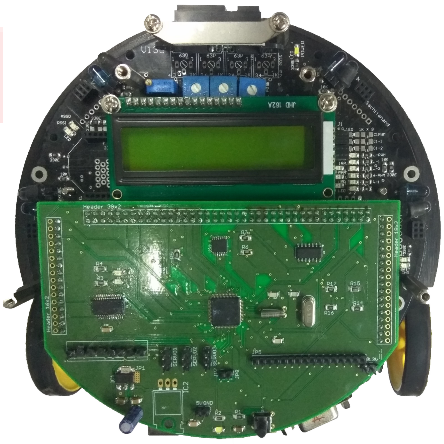


Figure25

1.4 Software and Code

Github link for the repository of code

1.5 Future Work

1. Create GUIs for user-friendly interface.
2. TI-RTOS can be used in real-time multitasking applications.
3. Programming through bootloader.
4. The TIVA based Firebird V can be extensively used for prototyping.
5. Real time debugger hence can be used in algorithm testing.

1.6 Bug report and Challenges

1.6.1 Bug report

Plug and Play Board Version 1:

1. 7805 Placement: The 7805 was not positioned at the end. Becuase of this there was no sufficient space to add the heat sink.
2. Port Expander Naming: The names of port expander are interchanged in the Daughter board. The names of port expander printed on the Daughter board are interchanged. Port B is named as port A and vice versa.
3. Switch Connection : The switch is used to connect the Ground of Launchpad and Daughter board for programming. The connections of this switch is incorrect.
4. The bot has to powered first and then micro USB should be connected to program the bot. This is because of the absence of switch explained in the previous step
5. LCD starts displaying data on alternate press of reset button. It gets initialised everytime but fails to display data.
6. Buzzer and red LED of TIVA launchad are on the same pin. Certain motors pins and red and green LED pins also overlap.

All these errors are rectified in the version 2 of Plug and Play board. **uC based board :**

1. RX and TX LEDs: LEDs attached to RX and TX pins of serial communication are not woring. The bot is able to communicate with the laptop serial but the LEDs are not glowing.

2. Crystal Placement: The Crystal is placed far from the microcontroller. Because of this the inductance of wires may effect the crysal frequency.

3. Heat Sink: The heat sink provided for LM1117 is not sufficient.

4. Naming : The names of port expamders, servo headers, programming headers are not printer on the board. The names of SCL and SDA pins on the board is interchanged i.e SCL pin is printed as SDA and vice versa.

5. The bot does not get programmed everytime because of connection problems.(Resolderig the pins of uC might help solve the problem)

6. LCD starts displaying data on alternate press of reset button. It gets initialised everytime but fails to display data.

1.6.2 Challenges Faced

1. Voltage Incompatibility: Firebird operates at 5v and TIVA board operates at 3.3v. So to interface TIVA board with Firebird V, we need level converters. The first one uses a diode in reverse bias condition to convert 5v to 3.3v. The second one uses BJT in cut off and active region to bring about the same functionality. By replacing BJT with MOSFET, it acts as a bidirectional level converter. Commercially this is available as BSS138.

2. Unavailability of Firmware for programming TM4C123GH6: The TIVA Launchpad has two arm Cortex M4 microcontrollers. One of the controllers is specifically used for programming the general purpose controller. But the firmware for this is not open-source. So, it was decided that there will two different schematics of daughter board will be created.The first one will be a simple plug and play board using TIVA Launchpad as the main board. The other one will be a board that is completely designed on the single PCB with an external programming circuitry.

3. Limited number of ADC Channels: Due to 12 ADC channels on TM4C123GH6PM controller, all the sensors on the firebird can not be interfaced directly. So an external ADC chip that works on I2C protocol will be interfaced with the daughter board to include all the sensors. After a thorough discussion, "ADC128D818 " was chosen. This has a 12-bit precision with 8 channels and can be interfaced using I2C communication, hence requires only 2 pins to be interfaced.

4. Voltage Divider: The sharp sensors present on the Firebird operate on 5 volts i.e their output varies from 0-5v depending on the position of the obstacle. So there is a need for voltage divider, but the traditional voltage works on the assumption that there is no current drawn from the dividing node. Hence a buffer is used to stop the current. Again there are two choices, BJT in common collector mode and opamp. Simulating the above two circuit in Proteus, Common collector BJT has a gain of around 0.8 and opamp had a gain of around 1. Hence opamp is used in this board.

5. Soldering the SMD components on the board.

Bibliography

[1] TIVA and code composer studio from the following sources

- TM4C123G LaunchPad Workshop
- Workshop By IITB

[2] Eagle tutorial from this link